NASA's Science Rover for MUSES-C

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Abstract

JPL is building an instrumented rover to be carried by the MUSES-C spacecraft to an asteroid to make *in-situ* scientific observations from the asteroid surface. It will be able to move about and point its instruments under direction of scientists on Earth. The small, lightweight vehicle has been designed to support its scientific mission while meeting the demands of the microgravity asteroid environment.

1 Introduction

The ISAS MUSES-C spacecraft, to be launched in 2002, will execute the world's first asteroid sample return mission. It is also planned that the spacecraft will carry a NASA-built rover to the asteroid.

ISAS and NASA are planning to cooperate on the mission in several areas [1].

NASA is providing a rover capable of *in-situ* scientific observations of the asteroid, Deep Space Network tracking, navigation support, testing of the ISAS return capsule heat shield at NASA's Ames Research Center, reentry targeting, and retrieval of the sample return capsule in the US.

ISAS is providing transportation of the NASA rover to the asteroid and command and telemetry communications through the MUSES-C spacecraft and ground system to the JPL Rover Control Workstation on site at ISAS. ISAS also will transfer a portion of the returned asteroid sample to NASA.

Both sides are providing science investigators for the MUSES-C spacecraft and NASA rover instruments and for analysis of the returned sample.

2 Mission Overview

2.1 MUSES-C Science

The science goals of MUSES-C are to learn about an asteroid through three classes of scientific investigations:

- Asteroid sample return and analysis.
- Remote sensing from the vicinity of the asteroid.
- *In-situ* observations from the surface of the asteroid.

2.2 MUSES-C Mission

Table 2.2 shows significant events outlining the mission to the asteroid 1989ML [2].

After arrival at the asteroid, prior to taking the first sample and deploying the rover to the surface, the MUSES-C spacecraft will spend approximately two months making remote sensing observations in order to characterize the asteroid.

The rover will be released during the first sampling sequence and will be able to perform surface operations for the remaining approximately four months until the spacecraft departs the asteroid for return to Earth.

Event	Value
Launch date	5 July 2002
Max sun range outbound (AU)	1.4
Max Earth range outbound (AU)	1.87
Asteroid arrival date	20 October 2003
Sun range during at asteroid (AU)	1.11 - 1.33
Earth range during at asteroid (AU)	1.86 - 2.33
Asteroid departure date	15 April 2004
Max sun range inbound (AU)	1.44
Max Earth range inbound (AU)	2.44
Landing date	5 June 2006

Table 2.2: MUSES-CN 1989ML mission events.

2.3 Asteroid Characteristics

The current understanding of target body (10302) 1989ML characteristics [3] is summarized in Table 2.3.

Characteristic	Value
Absolute magnitude	18.85 (assuming slope parameter G = 0.15)
Albedos assumed to place limits on effective radius	0.04 & 0.15
Effective radius (km)	0.3 - 0.6
Axial ratio	1.7 (lower limit)
Bulk density (g/cc)	1 - 3
Rotation period (hrs)	19.09 (+/- 0.20)
Spectral class	C (still a bit uncertain)
Escape vel. (m/s)	0.2 - 0.8
Surface gravity (cm/s**2)	$(0.8\text{-}5.0)\text{x}10^{-2}$
Colors	B-R = 0.029 +/- 0.065 V-R = 0.018 +/- 0.199 I-R = -0.026 +/- 0.056 R = 17.857 +/- 0.199
Perihelion dist. (AU)	1.10
Aphelion dist. (AU)	1.45
Orbital period (yrs)	1.44

Table 2.3: MUSES-CN 1989ML characteristics.

3 Design

3.1 Constraints on Rover Design

The mission and target body characteristics listed above impose constraints (Table 3.1) which drive rover design.

Mission Constraint	Rover Design Constraint
Transport to asteroid	Mass
Earth-asteroid distance	Communications throughput
Sun-asteroid distance	Power
Gravity	Driving speed, hop planning
Rotational period	Daily operations planning

Table 3.1: Rover design constraints.

3.2 Rover Science Instrument Package

The rover has three science instruments (Table 3.2): an active pixel sensor camera with actuated mirror and focussing mechanism capable of taking close-up and panoramic images, an infrared point spectrometer, and an additional spectrometer capable of determining elemental composition of the asteroid surface [4].

Instrument	Capability
Camera	256 x 256 Active Pixel Sensor, 20 micron pixels 10-position filter wheel (6 for science)
Near-Infrared Spectrometer	0.9 - 1.7 mm spectral range Spectral resolution <20 (expect 5)nm
Additional Spectrometer	Measures elemental abundances of surface soils and rocks

Table 3.2: MUSES-CN rover instrument capabilities.

These instruments have been arranged into a compact package (Figure 3.1), forming the basis of the rover body.

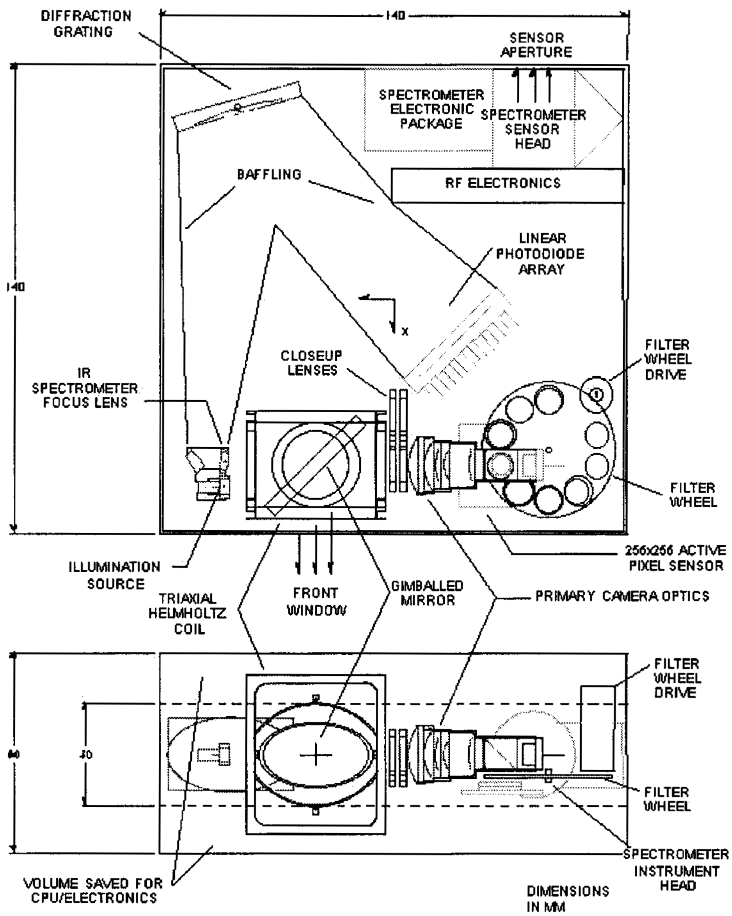

Figure 3.2: MUSES-CN Rover Instrument Layout.

3.3 Pointing / Mobility System

The rover wheels are mounted on struts which can rotate relative to the rover body (Figure 3.3), giving the rover the ability to orient its body in any direction relative to the surface for pointing and placement of its science instruments, or for righting itself if it lands on its back. The struts can move independently, giving the rover the ability to achieve four-wheel contact with the asteroid surface. The struts also give the rover the ability to hop.

For dead-reckoning and fine positioning, the rover will travel at 1.5mm/sec. It is planned for the rover to be able to hop tens of meters at 20cm/sec.

The rover uses skid-steering to turn.

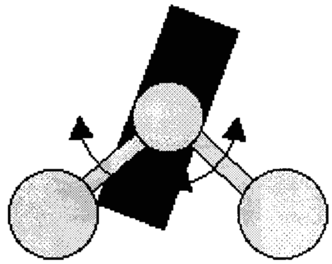

Figure 3.3: Struts move for righting, hopping, and instrument pointing and placement..

3.4 Rover Design Summary

The four-wheeled rover will have a mass of approximately 1.25kg, with a body approximately 14mm x 14mm x 6mm high. The 6.5cm diameter wheels have sensors to infer contact with the asteroid surface. The rover has solar cells on all sides providing 2.9W of power at normal sun incidence angles and has no battery. It has a radio on top for command and telemetry communications at 9600 baud with the Orbiter-Mounted Rover Equipment (OMRE) on board the MUSES-C spacecraft above the asteroid.

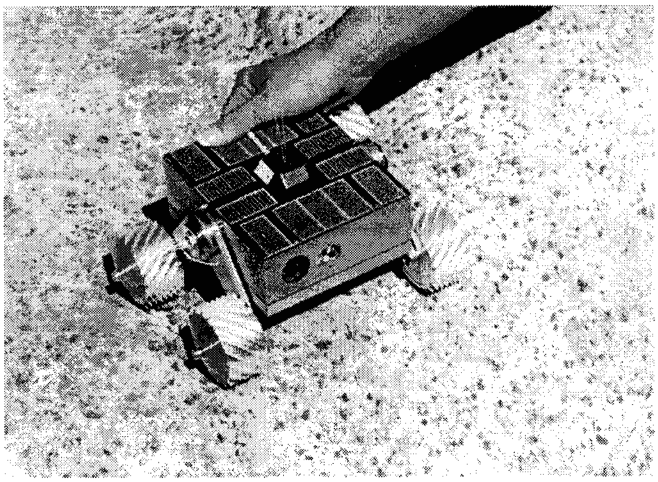

Figure 3.4: An engineering model of the NASA rover..

4 Conclusion

NASA is building a rover to be carried by the MUSES-C spacecraft to the asteroid 1989ML. Two concepts have been the key to achieving a compact low-mass design embodying a high level of science capability:

- The rover body is instrument package.
- The mobility system is pointing system.

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References

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